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AUTHOR Hurd, Paul DeHart
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ABSTRACT

This presentation focuses on bridging one of the many gaps that exist between educational research and the practice of science teaching, examining research (known as qualitative research) which involved the analysis, synthesis, and interpretation of data to serve practical ends better. Data analysis is done in a systematic way to identify conditions, themes, concerns, and circumstances stimulating the demand for educational reform in American schools. The database for this research is derived from educational issues that have their origin in social processes and from those generated by public pressure (such as the back to basics movement and the evolution/creation controversy). The presentation also discusses research findings on the flavor and mode of the reform movement in science education in the United States. A summary of recommendations found in these national studies (which used naturalistic research techniques) shows several patterns of agreement on new directions for science education. For example, the overall purpose of education in the sciences is to develop culturally literate and responsible citizens for participating in a modern science/technology oriented democracy. In addition, the core curriculum should be a balance of science and technology presented as an integrated system and include both biological and physical science concepts. (JN)

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UPDATE ON SCIENCE EDUCATION RESEARCH:

THE REFORM MOVEMENT

Paul DeHart Hurd

Professor Emeritus of Education
Stanford University

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I

The potential contributions of research and development activities designed to improve student learning and educational practice are far from fully realized. Only recently have efforts been made to integrate educational research, development, communication, and practice in a functional way. So far almost no progress has been made in opening pathways to feed insights and experience from teachers back to researchers. My talk today is focused on bridging one of the many gaps that exist between educational research and the practice of science teaching.

The research I will be describing is of a different sort than is usually reported in the literature. It goes beyond empirical or statistical studies in the quest for a conceptual framework, a rationale, or a vision that

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provides insight into what science education ought to be about.

The data base for this type of research is derived from educational issues that have their origin in social processes: the changing image and ethos of science, cultural shifts, social and economic trends, and national education policy perspectives such as those of equity and vocational training. There are also educational issues generated by public pressure that are studied: the back to basics movement, the evolution/creation controversy, and the demands for sex, drug, energy, environmental, nuclear, human genetics, and metric education. The findings of national surveys on the status of science education in the United States must be examined from different points of view and interpreted; examples are those conducted by the National Science Foundation, the National Assessment of Educational Progress, the Gallup and other polls on education, the National Academy of Sciences, and the National Center for Education Statistics. Congressional and state legislature hearings on science, technology, and education provide another source of data.

Of special interest are the data found in the national reports on the condition of education in the United States. These reports, all published since 1982, are of two general types: one is based on observations of schooling by

individual analysts, for example, those by Goodlad, Sizer, Boyer, Lightfoot, and Lipitz; the other type consists of commission and panel reports such as those of the Commission on Excellence, the Report to the National Science Board, the Paidea Group and over two dozen other nationally representative commissions, and there are more to come. One cannot help but be impressed by this sudden outburst, this tremendous public outcry for the reform of education in America. Why is it thus? Why is the pressure for educational reform a worldwide movement? What went wrong? What is meant by a reform for excellence in science education?

The answers to these and related questions about science education are to be found in the different data sources I have just described. To find these answers requires that the data be analyzed, synthesized, and interpreted. The analysis of data is done in a systematic way to identify conditions, themes, concerns, and circumstances stimulating the demand for educational reform in our nation's schools. This type of research is known as qualitative or theoretical, yet its purpose is to serve practical ends better. A famous scientist once commented that "nothing is so practical as a good theory." It should be noted that data for qualitative research consist almost entirely of words rather than numbers.

The last step is a synthesis of the data to evolve a conceptual framework or a strategic vision for a reform of science education. Among the values of a conceptual framework are these:

1. It is not possible to effect a reform of science education or assure improvements in curriculum and learning in the absence of purpose.
2. We cannot hope to reconceptualize a direction for reform by a statistical analysis of quantitative or empirical research.
3. A strategic vision of science education must precede strategic planning for change; otherwise, actions are likely to be counter-productive.
4. Without a clear vision of what we expect students to gain from an education in the sciences, it is not possible for us to make a worthy interpretation of research, to distinguish frivolous actions from those truly supportive of a reform, or defend the changes we believe are sound.

A final note--If you do not know where you want to go, how you are going to get there, and what you expect to do when you arrive, the findings from quantitative research are of limited value. The bridge between research and practice is a well conceived conceptual framework of what an education

in science should be like. A conceptual framework is not intended to solve problems, but to sharpen our commitments as teachers and provide a frame of reference to interpret the findings of research, guide policies, and identify directions for reform.

II

The remainder of my presentation is a report of research findings on the flavor and mode of the reform movement in science education in the United States. The study was carried out by using qualitative research techniques and the data sources previously described.

More than thirty national commission reports on education published in the past two years have affirmed the importance of science in the education of every individual. Science is recommended as part of a core curriculum to be taught at each grade level from kindergarten through grade ten--a minimum of 2,000 hours of instruction--as a graduation requirement for all students. Students are no longer to be given the option of electing ignorance of science and technology and choosing cultural deprivation as a way of life.

Members of the state and national commissions generally have not been happy with science courses as they are now organized and taught in schools. They believe there is need for a new vision of science education and a rethinking of instructional goals. The commission members base this recommendation on the following observations: 1) much of the cultural and economic uniqueness of the United States arises from achievements in science and technology; 2) citizens of this nation are increasingly called upon to make decisions that demand an understanding of science and technology for a reasoned judgment, for example, on such issues as energy sources, health practices, environmental management, and a personal choice of life-style; and 3) since the future is not entirely predictable students must be equipped with lifelong learning skills; the teaching of science should be oriented toward the future that young people are expected to help define and shape. In these terms the commissioners found the present science curriculum inadequate for life, living, and learning in a high-technology democracy. The conclusion drawn was that the nation's children are growing up as foreigners in their own culture, scientific and technological illiterates, unable to assume

their duties as responsible citizens or relate the science they have learned to human affairs and social progress.

How do we deal with this criticism? A purpose of this conference is to consider that very question. The answer is to be found by examining the image and ethos of modern science and technology, cultural shifts, social and economic trends, and human experience as it is today.

The basic pattern for rethinking the purposes of science and technology in general education is sufficiently different from present criteria for science curriculum development that we would be better off to forget our historical past. What we must do is think through a new vision of science education. Dusting off old goals and behavioral objectives, updating bits and fragments of subject matter, and acquiring new educational technology will not bring about the reform deemed necessary. To establish a new conceptual framework for science education we might begin by asking the question: What should young people know, value, and be able to do to be considered scientifically and technologically literate in our high-technology nation and its likely future?

A good place to start deliberations is with a study of the nature and culture of modern science and technology.

Over many years, and especially since World War II, science as an enterprise and as an endeavor has been undergoing major changes. The classical descriptions of science and its methods of inquiry found in the majority of textbooks represent at best a description from a past century.

Just how has science been changing? After a long period of cautious association, science and technology are nor longer distinct enterprises but form an integrated system. Progress in scientific research depends increasingly on the instrumentation that technologists and engineers provide. New instruments make it possible for scientists to ask more sophisticated and penetrating questions. It is difficult to know whom to credit with a new discovery. Should it be the technologists who designed the electron microscope and revealed more parts to a cell than one can name in a month's time? or the engineers who developed the two-mile-long linear accelerater that has enabled scientists to identify more than 37 particles in the atom? or the genetic engineers who made biology a new science? or the scientists who apply a new technology to problems previously unsolvable for the lack of appropriate instrumentation?

Derek DeSolla Price in his George Sarton Memorial lecture at the 1983 annual meeting of the American

Association for the Advancement of Science defined modern science as "applied technology," and also pointed out that nothing in the way science takes place today can be generalized as a scientific method (1). Every Nobel prize in 1984 in biology, chemistry, and physics was awarded for a technological achievement. Currently 60 percent of all research scientists are employed in either industry or the armed services. This is not the image of science found in science textbooks. One purpose of the reform movement is to promote a more authentic view of science and technology in the school curriculum.

In recent years the scientific endeavor, like technology, has become important in framing economic, social, and political policies in the United States. Society in turn has more to say about the direction of research. For example, much of the financial support needed for basic research depends upon where the federal government wisnes to assign tax dollars--shall it be for seeking the causes of cancer? devising more effective weapons of war? or exploring black holes in the heavens? The public would like to fuse social purpose and human betterment with scientific research and technological innovation in ways most likely to advance the quality

of life. This is also the mode in which the public would like to see the basic core program in science taught. The idea is not new: Francis Bacon in 1620 wrote that the "ideal of human service is the ultimate goal of scientific effort"(2).

In the last decade nearly one thousand colleges and universities have developed new course offerings to consider the interactions of science/technology/society with such titles as:"science, technology, society and values," "bioethics and biotechnology," "science and public policy," "science and the humanities" (3). These are science courses in which the emphasis is upon the impact of science and technology on modern life, current thought, civic competence, and human affairs. It is this point-of-view that the national commissions visualize for science courses that will make up the core curriculum in elementary, middle, and secondary schools.

As science has become more broadly integrated into all phases of our culture, its educational significance for the individual has also increased. Citizens are required more and more frequently to make decisions about problems that have dimensions in science and technology as well as value and ethical considerations. Examples of these problems are those related to managing our natural and social environments, transplanting natural

or artificial human organs, dealing with genetic engineering, using mechanical support systems for sustaining human life, developing nuclear energy, controlling human overpopulation, and replacing people with robots. These are issues that require a knowledge of science and technology interpreted in terms of human values, ethics, and moral judgments. The present science curricula, if they deal with ethics and values at all, do so only if they are internal to a scientific discipline, for example, intellectual honesty in reporting data, priority of recognition for a discovery, and the necessity for verifying experimental results. Stephen Toulmin, a philosopher of science, expresses the current view with the comment that "... it is no longer possible to draw so clear or sharp a line between the intellectual demands of good science and the ethical demands of the good life" (4).

To further clarify the quest for a new vision of science education I will use the words from several national commission reports. The Report to the National Science Board describes the rationale for science teaching in this way (5):

> The nurturing in the general population of enough familiarity with science and technology facts and concepts and the facility with problem solving strategies needed so that every person can cope adequately with their role as decision makers in our technological democracy.

Furthermore, the Report continues, everyone should receive the "scientific and technological knowledge needed to fulfill civic responsibilities, improve the student's own health and life and ability to cope with an increasingly technological world" (6).

The National Commission on Excellence in Education describes the goals for science education as follows (7):

> The teaching of science in high schools should provide graduates with an introduction to: (1) the concepts, laws, and processes of the physical and biological sciences; (2) the methods of scientific inquiry and reasoning; (3) the application of scientific knowledge to everyday life; and (4) the social and environmental implications of scientific and technological development.

In addition, the Commission recommends that all schooling include (8):

> ... intellectual, moral, and spiritual strengths of our people which knit together the very fabric of our society. The people of the United States need to know that individuals in our society who do not possess the levels of skill, literacy, and training essential to this new era will be effectively disenfranchised, not simply from the material rewards that accompany competent performance, but also from the chance to participate fully in our national life.

An important science objective implicit in the recommendations from different panels and commissions is the optimal utilization of knowledge. One meaning of excellence in education is the ability of students to be able to use what they have learned. Traditionally, in science teaching the focus has been limited to learning terms and acquiring a fund of factual information. Typically a junior high school science textbook features 2,000 or more terms with the number increasing to around 5,000 in a high school chemistry text. Most of the facts are accurately stated though there is doubt as to whether they are important for even a scientist to know. For the non-specialists most of these facts and terms are "inert" in the sense they have little value in the real world of life and living. Critics point out that for all the science facts acquired, students exist in an informational vacuum unable to make use of what they have learned in either personal or civic affairs. Alfred North Whitehead, famous Harvard philosopher, once commented "if knowledge is not useful what is it?"

We often identify this period of history as the "information age" where knowledge is considered our greatest human resource and the only inexhaustible one. The competitive strength of individuals as well as that of the nation depends upon a capacity to acquire, relate, and apply information. Now that computers provide us

with an external memory system capable of storing and retrieving on a moment's notice millions of facts, we have the problem of how to process the information with insight and wisdom. The process is called reasoned thinking which in turn is dependent upon such supporting intellectual skills as those of collecting, analyzing, synthesizing, interpreting, and evaluating information. These are skills that can be effectively developed only in the context of problems, they cannot be taught directly. This is the argument for the organization of much of the science curriculum in terms of problems--real-life problems involving science, technology, and engineering concepts.

It is not possible here to elaborate upon all the conditions important for the optimal utilization of knowledge, but a comment is necessary about what is meant by the reliability or quality of information. Reliable knowledge in science is a product of research that has been verified by other researchers. People, however, use an enormous amount of questionable information for the decisions they make. An important goal of science education is to see that students acquire a conscious awareness and sensitivity that enables them to distinguish 1) evidence from propaganda; 2) probabilities from certainties; 3) rational beliefs from superstitions;

4) science from myth and quackery; 5) data from assertions and fantasy; 6) fact from fiction and folklore; 7) sense from nonsense; 8) credible from incredible; 9) theory from dogma; and 10) knowledge from opinion. An understanding of these attributes is essential for translating what students learn into rational thinking and informed decisions.

Earlier I mentioned that much of the information in the typical school science courses is "inert" for anyone but a research specialist. A task in the reformulation of science education is an extensive reassortment of all that is known in science and technology to select the concepts, principles, and laws that ramify most widely in human affairs. What is sought is knowledge that has both scientific and cultural validity. The Paideia Group in their report state the essential criteria for selecting new subject matter for a core program as follows:

> "it should...provide the learner with indispensable knowledge about nature and culture, the world in which we live, our social institutions, and ourselves," as well as "...prepare <u>all</u> [students] for the continuation of learning in adult life, during their working years, and beyond" (9).

A summary of the recommendations found in the national studies shows the following patterns of agreement on new directions for science education:

1. The overall purpose of an education in the sciences is to develop culturally literate and responsible citizens for participating in a modern science/technology oriented democracy.
2. The core curriculum should be a balance of science and technology presented as an integrated system and include both biological and physical science concepts.
3. Science and technology should be taught in the context of the nation's social system with a focus on common goals and shared values that emphasize a concern for the common good, human betterment, progress of the nation, and the well-being of the individual.
4. Students should acquire the intellectual skills essential for processing and utilizing information as it relates to critical thinking, decision making, independent learning, and ethical judgments.
5. All students are to have an equal opportunity to be scientifically and technologically

literate so that they may participate more fully in our culture, in human affairs, and their own development.

Where do we begin in developing a quality science program called for in the state and national commission reports? A first step is for science teachers in the elementary, middle, and secondary schools to meet regularly for the next few months to discuss what it is they believe every student should know, be able to do, and value from a study of science. After preliminary discussions among yourselves, invite as many scientists, technologists, engineers, and philosophers or sociologists of science as might be available to participate in further discussions. These deliberations should result in a written consensus document that expresses what you believe and are willing to defend as an appropriate education in the sciences for <u>all</u> students.

I should warn you that some teachers do not accept the idea of science as a basic in the education of every student. These teachers should have the opportunity to prepare a statement explaining why some students should not be permitted to take their course. Do not expect that everyone will fully agree upon whatever conceptual framework you evolve. It is essential to keep

in mind that the task is to define the perspectives, human priorities, and the context of a science curriculum that will enrich the lives of young people for the present and future as well as contribute to our national well-being.

With a conceptual framework that embodies the new image of modern science and technology, a higher conceptual level of knowledge and intellectual skills, and a clarification of goals, we will be on our way to new standards of excellence in science education.

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